UDC 67

RESEARCH ON THE IMAGERY MODELING OF ELECTRIC VEHICLE STEERING WHEEL BASED ON BP NEURAL NETWORK

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Introduction. The steering wheel, as an important part of the car interior, reflects the aesthetics of the car and users tend to select and evaluate products based on the emotions and images (Kansei in Japanese) in their minds. Kansei engineering understands the emotional needs of users and assists in the design and evaluation of solutions by capturing their Kansei of product features [1].

This study takes the Z-era group (young people born between 1995 and 2009) in China as the target group. A new method for describing the steering wheel shape of electric vehicles is proposed by combining morphological analysis, deconstructing the steering wheel shape through the hierarchical relationship of "shape composition - shape features - shape factors", establishing a BP neural network scoring prediction model, and testing the reliability of the model. It helps designers to quickly grasp the user's perceptual needs using quantitative methods to assist in design and decision making.

Related works. The steering wheel shape affects its functionality and the user's emotional imagery. For example, the round steering wheel has better operational continuity, and the D-shaped steering wheel increases the user's leg space [2]; the two-spoke steering wheel gives a simple, futuristic image, but is less stable; the three-spoke steering wheel has a dynamic, exciting image and better stability [3]; the size of the space above the spokes affects the user's view of the dashboard, etc.

The current research on Kansei engineering of steering wheels is as follows: Ding Man et al. established a product appearance imagery evaluation model based on support vector machine regression and simulated annealing algorithm, and explored the association between steering wheel shape, color and material and users' emotional needs [4]. Zhao Deng et al. used Kansei engineering and fuzzy integrated evaluation methods to tap the emotional needs of youth groups and constructed an appearance imagery model for electric vehicle steering wheels [5]. Wenwen Lei et al. counted the mean value of the association frequency between the interior design elements of production and concept cars and the sense of technology, and explored the relationship between the interior design elements, type elements and the sense of technology [6].

Based on the psychological theory of sound loudness, Fu-Xi Liang et al. proposed a theoretical model of automotive interior quality loudness, and established a regression model of user automotive interior goodness and quality quality, taking the automotive steering wheel as the research object, to explain the relationship between quality sense and user preference [7]. Wang Z. Hao analyzed the shape and structure of automotive steering wheels and proposed an innovative design strategy for intelligent steering wheels [8]. Chang et al. used multiple linear regression analysis to construct a model of users' emotional perceptions of automotive steering wheels, demonstrating that aesthetics, operational strength, and modernity are three key factors that influence users' emotional perceptions of steering wheel design [9]. Current steering wheel-related Kansei engineering research focuses on the relationship between local steering wheel shapes and emotional imagery, while research on the interrelationship and layout of steering wheel shapes and studies for specific populations are still rare.

According to a survey conducted by China's Daily Economic News [10], most of the Generation Z group has a high willingness to purchase electric vehicles, and in terms of model selection, the Generation Z group prefers the labels of "hybrid/electric", "SUV", and "RMB150,000 to 200,000/100,000 to 150,000", which provides a design reference for the electric vehicle products for the Generation Z group.

BP neural networks are multilayer feedforward neural networks trained using the error backpropagation (Backpropagation) algorithm [11], and their network structure contains input, hidden and output layers.BP neural networks have good ability to map multidimensional functions [12] and are often used for prediction, evaluation and classification of results in a fast manner.

To analyze and predict product styling, Kansei engineering needs to analyze steering wheel styling using morphology in addition to obtaining the corresponding weights. Since the granularity of interrelationships and layouts between shapes is too small to be evaluated directly, this paper uses BP neural networks to construct a regression prediction model between steering wheel shape factors and emotional imagery scores based on deep learning theory.

Methods. In this paper, we deconstructed the types of electric vehicle imagery styling preferred by Chinese Generation Z, quantified the importance of steering wheel styling factors using hierarchical analysis, constructed a BP neural network scoring prediction model and verified the reliability of the model, with the following main research ideas:

1. **Collect sample images according to the target population.**

On the website of AutoZone, "price range 100,000-200,000 RMB", "SUV", "small/compact", "pure electric/extended program" were used as the filtering criteria. "We filtered the electric car models released in the past two years and collected pictures of the front of the steering wheel that met the criteria. The images with poor angles and blurred features were removed, and a total of 40 steering wheel samples were collected. The samples were de-colored and masked to obtain the SUV electric vehicle steering wheel research sample library.

2. **Constructing a hierarchy of styling progression.**

Based on the steering wheel styling design, following the styling description method of "styling composition - styling feature - styling factor", the steering wheel styling is decomposed into two types of styling composition: local styling and layout connection.

Among them, the local modeling includes spoke modeling, wheel modeling, disc body modeling and bottom width modeling.

Spoke modeling includes double-width type, three-spoke perforated type and three-spoke non-perforated type.

The disc wheel shape includes three types of square circle, D-shaped and rounded rectangle.

Disc body shape includes inverted trapezoid, rounded rectangle, round type, octagonal, pentagonal, hexagonal a total of 6.

The bottom width shape includes inverted V shape, positive V shape, organic shape, rectangle and no bottom width total 5 kinds.

The layout connection includes the side spoke orientation, the bottom width disc wheel connection shape, the control key layout on both sides, and the bottom width disc body connection shape.

The side spoke orientation includes upward tilt, downward tilt and horizontal orientation in total of 3 types.

The shape of bottom span disc wheel connection includes grooved, interleaved, connected, one-piece and bottomless span total 5 kinds.

The two side control layout includes symmetrical layout and asymmetrical layout totaling 2 kinds.

The shape of the bottom width disc body connection includes three types: connected to the disc hub, connected to the side width and bottomless width.

There are 8 types of modeling features and 30 types of modeling factors.

3.Parameterization of the importance of modeling features.

An expert group of eight design professionals was invited to discuss and form a unified opinion on the modeling composition and the modeling features within each group were scored using the nine-level scale method, a pairwise comparison matrix was established and a consistency test was performed, the weight vector of the corresponding layer was calculated by the arithmetic average method, and the total weight of each modeling feature in the modeling was calculated by multiplying the pairwise comparison matrix of each layer.

4. Filtering emotional imagery vocabulary.

A total of 59 imagery words about SUV electric steering wheels were collected from automobile evaluation websites and related research results, Through the questionnaire survey of the target group, combined with the group discussion and lexical check, we obtained five imagery words with high frequency and representing different aesthetic dimensions: " harmonious ", "stylish", "Practical" and "technological".

5.Product imagery questionnaire research.

The five imagery words and 40 samples were combined with the Likert 5 scale to build the electric car steering wheel imagery questionnaire, and the questionnaire was distributed to people aged 14-28 through the Internet, and 58 questionnaires were obtained. The mean value of electric car steering wheel imagery evaluation was obtained after the statistics of the research results.

6.Sample modeling factor coding.

Referring to the principle of sample modeling factor coding [13], the original coding of modeling factor was multiplied by the weight value of the corresponding modeling feature to code the sample modeling factor.The output data are normalized using the mapminmax function as the output layer parameters of the neural network.

7.Construction of BP neural network.

MATLAB was used to construct a rating prediction model between sample modeling factors and multiple product sentiment imagery. A feedforward neural network is created using the feedforwardnet function, a hyperbolic tangent function (tansig) is used as the activation function, and a linear function (purelin) is used as the activation function of the output layer, an error threshold of 1e-6 is set, the learning rate is 0.001, and the trainlm function is used to train the weights of the neural network.

8.Testing of BP neural network.

Due to the small number of samples in this paper, considering that the randomness of sample division and ranking may cause the prediction results of the model to deviate significantly from the true values [14] and lead to the reduction of the generalization ability of the model, the leave-one-out cross-validation method [15] is introduced to maximize the utilization of sample information and improve the reliability of the model.

The calculation of leave-one-out cross-validation was performed in MATLAB, and 40 leave-one-out cross-validations were performed on the prediction samples to obtain the imagery prediction values for each sample. The mean square error refers to the mathematical expectation of the squared difference between the predicted and true values [16], and the closer the MSE is to 0, the smaller the prediction error of the model. The mean squared error MSE of each imagery prediction value and rating value for each sample was calculated as in Table 1. the average mean squared error MSE_1 of each cross-validation was calculated, and the cross-validation model with the smallest MSE_1 was selected as the final rating prediction model.

Sample number	**Mean square error of imagery prediction and true evaluation value MSE**				
	harmonious	**liberal**	**stylish**	**Practical**	**Technological**
Sample 1	0.00043	0.02556	0.00007	0.01472	0.00020
Sample 2	0.00171	0.00123	0.01108	0.01539	0.01508
Sample 3	0.00623	0.00916	0.00428	0.00201	0.00144
⋮	⋮	⋮	⋮	⋮	⋮
Sample 39	0.01244	0.00759	0.03148	0.03377	0.00010
Sample 40	0.00414	0.03509	0.01564	0.03058	0.05248

Tab 1 Mean square error of imagery prediction and true evaluation value

Results. This paper deconstructs the car steering wheel shape based on the shape description method of "shape composition - shape feature - shape factor", and establishes a scoring prediction model through BP neural network and verifies the reliability of the model to help designers use quantitative methods to quickly grasp the Kansei of target users and assist in design and decision-making.

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